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MAGNETIC FIELDS AND THE FINE STRUCTURE OF THE CHROMOSPHERE IN THE ACTIVE REGION

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SUMMARY

The orientation of the fine structure of the chromosphere in active region of the Sun has been studied by using registrations of the transverse magnetic field and the H_α spectroheliograms. It was found that the orientation is determined by the force effect of the magnetic field that penetrates the chromosphere.

* * *

Photographs of the active region of the Sun, obtained with good images, show in the line H_α an entirely specific orientation of separate oblong elements (filaments), which in some cases form a vortex structure [1, 2]. Certain authors [1 — 4] assumed that this orientation is determined by the action of the magnetic field. Subsequently, this viewpoint was corroborated by direct comparison of chromosphere's fine structure in H_α with longitudinal magnetic field charts obtained at photosphere level [5]. However, it was pointed out in a later work [6], that the similarity of chromosphere's fine structure with the magnetic field is observed only in rare cases. Evidently, further research is necessary for the clarification of this question.

We have conducted the comparison of transverse magnetic field directions at photosphere level with the fine structure of the chromosphere (dark filaments) in the line H_α.

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* MAGNITNYYE POLYA I TONKAYA STRUKTURA KHROMOSFERY V AKTIVNOY OBLASTI

1. - The material was obtained in 1962 on the tower solar telescope of the Crimean Astrophysical Observatory [7], The field registration was conducted in the photosphere iron line 5250 Å by the method, worked out by Stepanov and Severnyy [8]. The minimum values of the registered fields was $\sim$ 100 gauss. The width and the height of spectrograph's slit were chose 0.3 - 0.5 mm at solar image diameter of 200 mm. The scanning by the slit of the magnetograph was effected along the daily parallel at 6"½ intervals (6.5"). In the final resort, the registrations were in the form of azimuthal charts of the H vectors in the pictorial plane.

The fine structure of the chromosphere was studied by the spectroheliograms, which were photographed in the morning at best hours for perfect images at solar image diameter of 110 mm (Fig. 1). The photos were usually obtained at the center of the line H_α , and at certain days — also at various distances from line center. The regions studied were chosen as close as possible to the central meridian, so as to decrease the projection effect. The registrations of the magnetic fields were conducted some time after photographing spectroheliograms.

The studied material was that obtained on 26 and 28 June, on 1, 12, 13 July and on 6, 7 and 9 September 1962.

Quite good conditions for observations took place on 7 Sept., 1962. In the photoheliogram obtained in integral light on that day, the structure and the penumbra of the spot were well visible.

2. - For the comparison of the orientation of the fine structure of the chromosphere with the direction of transverse magnetic fields, drawing of spectroheliograms with a magnification to the same scale as that of the magnetic field charts was done. Then, such sketches were superimposed the best possible way with the corresponding chart of the magnetic field. The daily parallels and the spots served as indicators.

The Figures 2 to 8 represent the azimuths of the transverse magnetic fields with fine structure of the chromosphere (dark filaments) drawn upon them at the center of the line H_α. In Fig. 8, the fine structure is obtained in the blue wing of the line H_α at 0.45 Å distance from center.

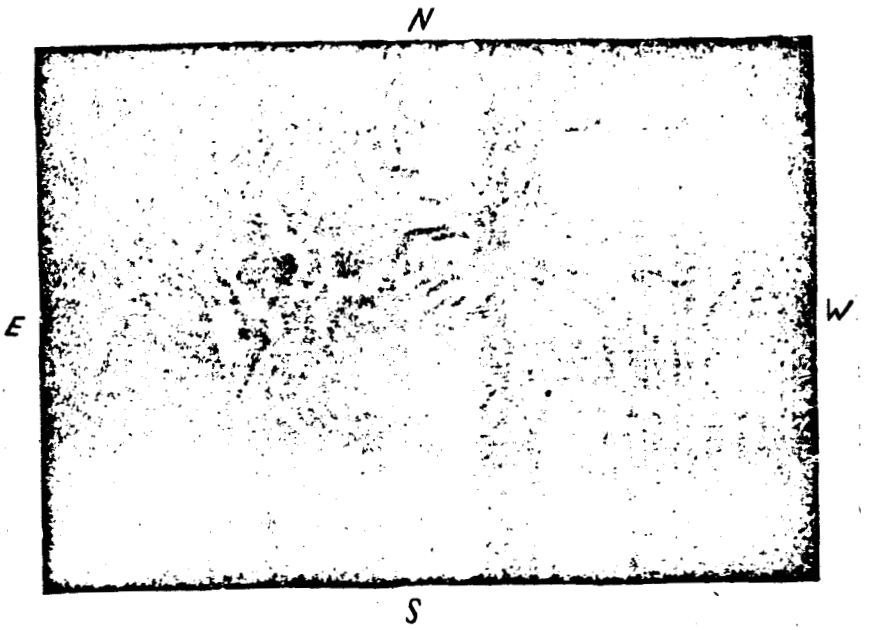

Fig. 1. Photograph of the active region in the line H_α for 7 September 1962
Sun's diameter = 33 cm.

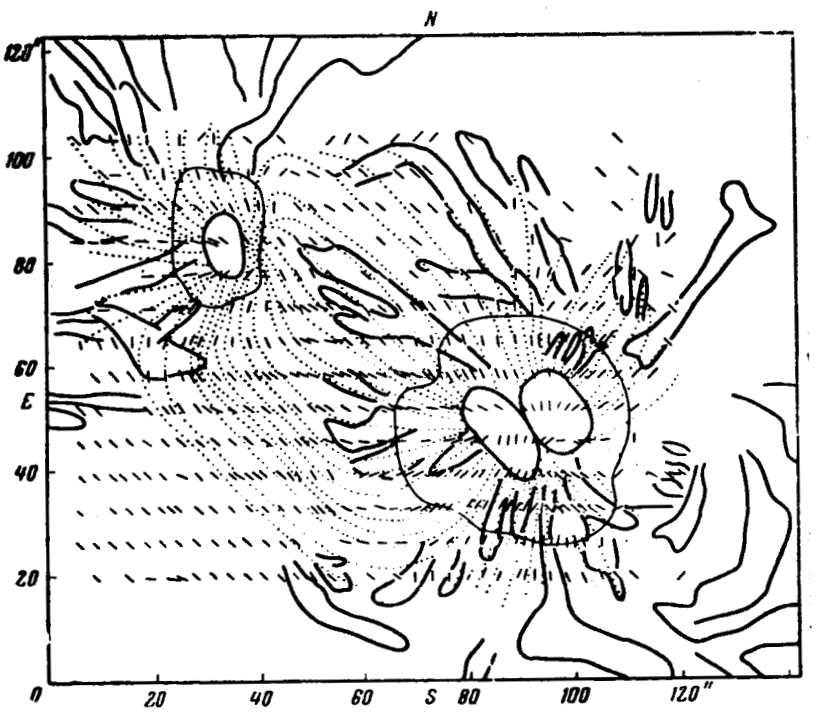

Fig. 2. - Sketch of vector's H azimuths in the pictorial plane and of the fine structure of the chromosphere at the center of the line H_α for 28 June 1962.
Photographing time of the spectroheliogram $t_1 = 6^h45^s$. Time of field reg. $t_2 = 10\,40 - 11\,25$ hrs. Strokes indicate the directions of vector's H projection on the pictorial plane. Dashes indicate the assumed variation in the direction of the field vector in projection on pictorial plane, Thin solid lines indicate penumbra contours and those of spot nuclei. Heavy lines denote the contours of filaments.

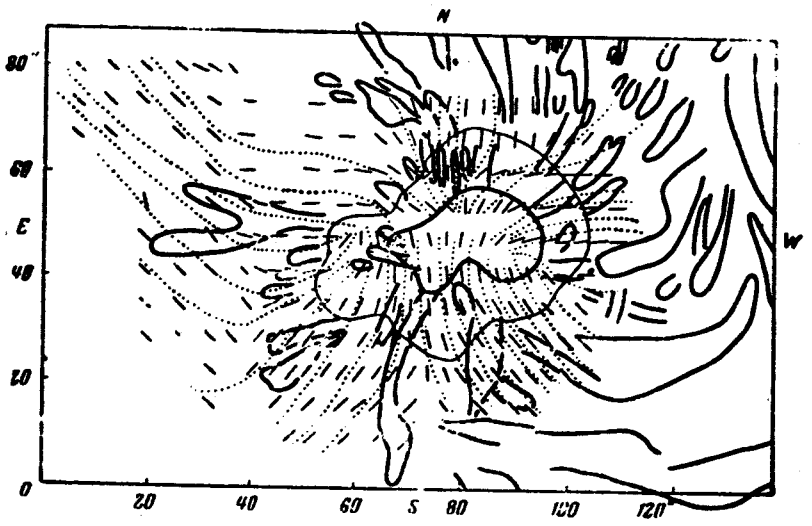

Fig. 3.- Scheme of azimuths of the vector H in the pictorial plane and of the fine structure of the chromosphere at the center of the line H_α for 1 July 1962.
t_1 = 07 47 hrs, t_2 = 11 35 – 13 00 hrs
Same denotations as in Fig. 2

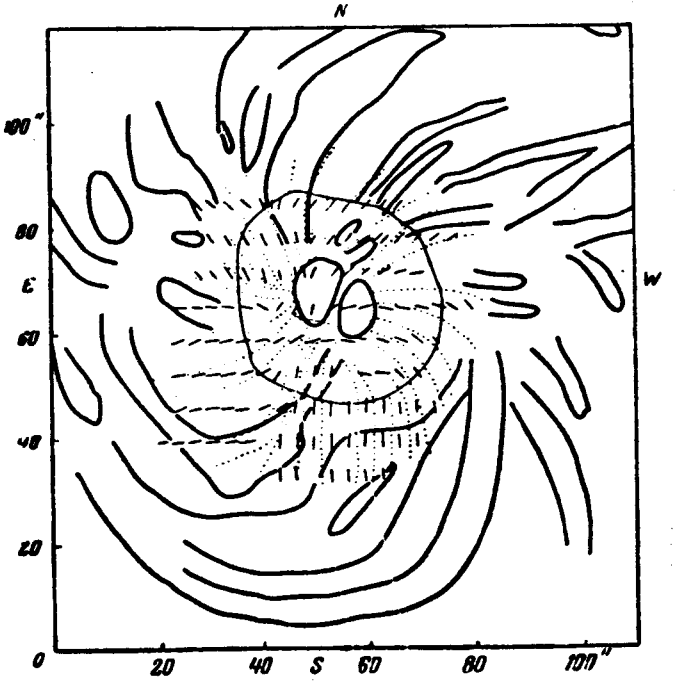

Fig. 4.- Same for 13 July 1962; t_1 = 06 34, t_2 = 09 30 – 10 23 hrs.
Same denotations as in Fig. 2

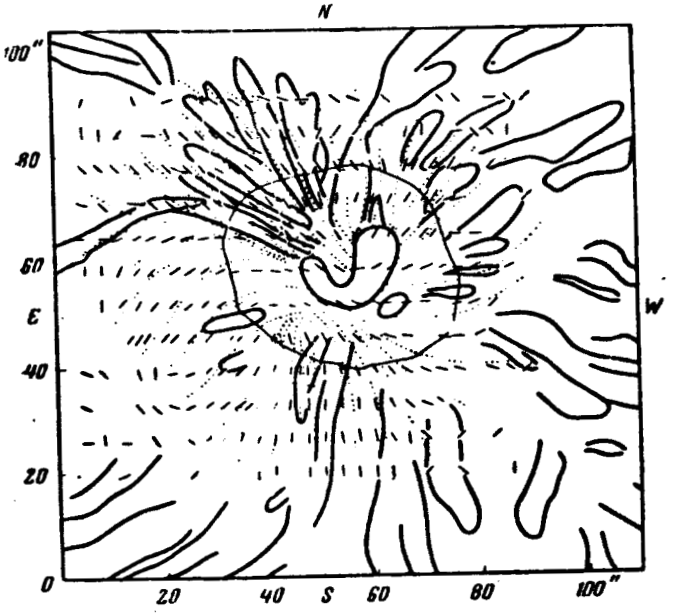

Fig. 5. - Same for 6 September 1962; t_1 = 07 28 hrs; t_2 = 11 09 –12 15 h. Same denotations as for Fig. 2.

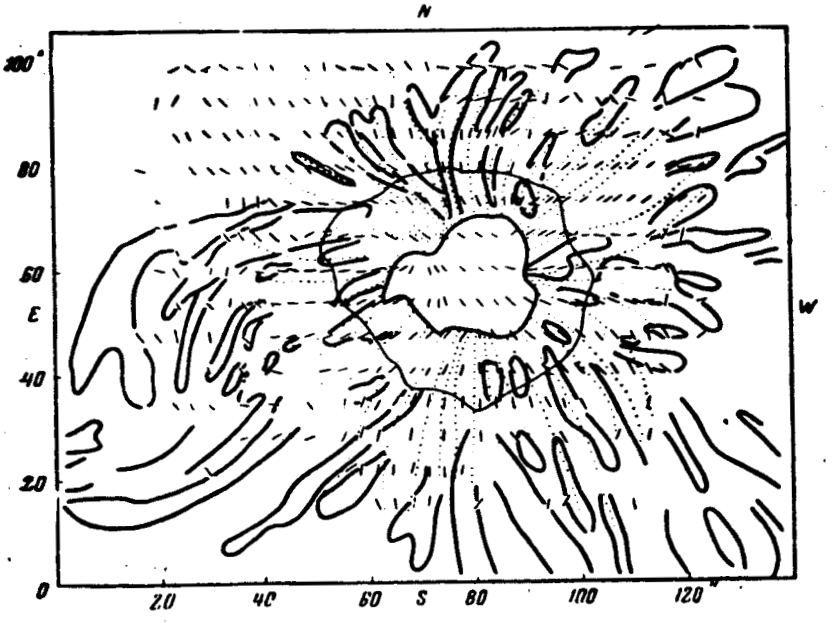

Fig. 6. - Same for 7 September 1962; t_1 = 08 00 hrs; t_2 = 12 15 – 13 10 h. Same denotations as for Fig. 2.

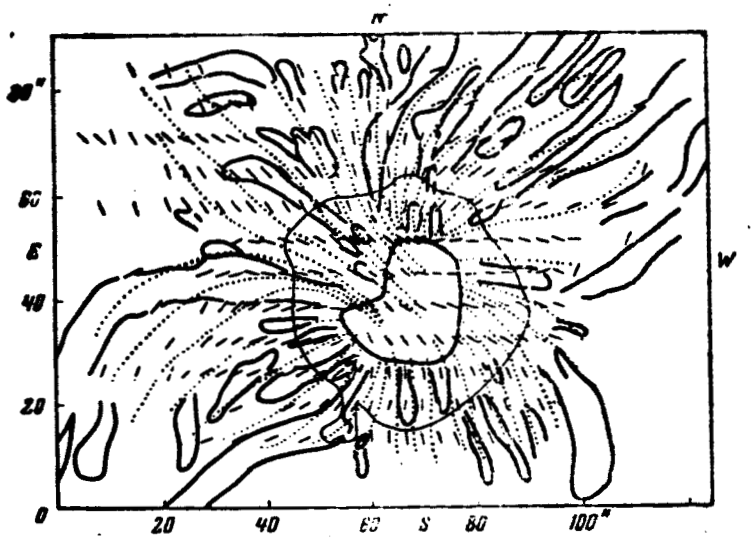

Fig. 7. - Same for 9 Sept. 1962; $t_1 = 07\,45$; $t_2 = 13\,05 - 14\,00$ hrs
Denotations as in Fig. 2.

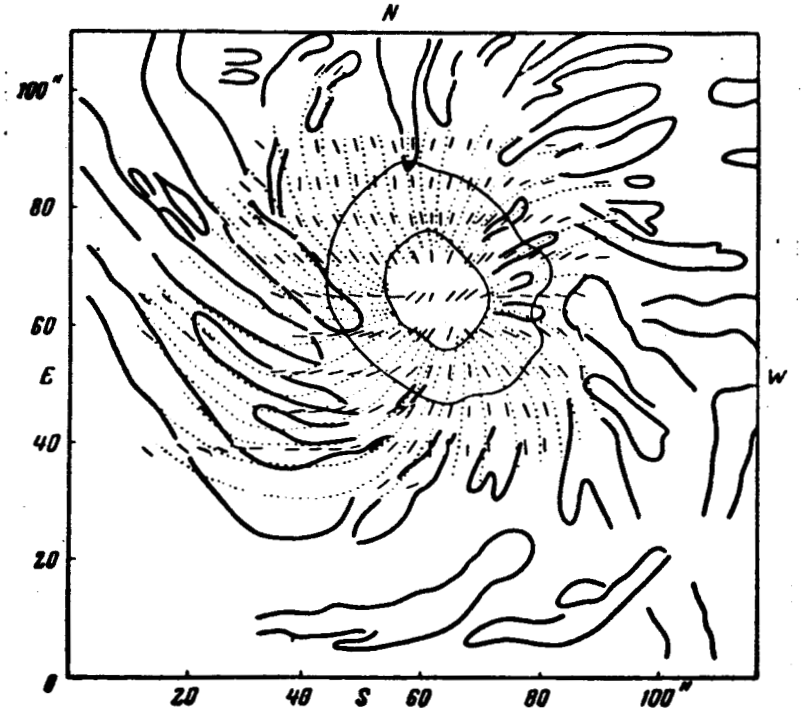

Fig. 8. - Scheme of vector's H azimuths in the pictorial plane and the fine structure of the chromosphere in the blue wing of H_α, $\Delta\lambda = 0.45$ Å for 12 July 1962.
$t_1 = 07\,20$ hrs; $t_2 = 07\,55$ hrs – $08\,50$ hrs.
Same denotations as in Fig. 2.

In all the figures the directions of the projection of magnetic intensity vector of H on the pictorial plane are plotted by strokes. The assumed direction of the field vector in the projection on the pictorial plane is indicated by dashes. The thin solid line outlines the contours of penumbrae and spot nuclei. Finally, the contours of dark chromosphere filaments are outlined by a heavy solid line. The registration and spectroheliogram photographing times are indicated in the figures.

As may be seen, there is a rather close general similarity between the direction of the magnetic field in the photosphere and that of chromosphere's fine structure elements at the center of the line H_α as well as at the 0.45 Å distance from it. The last case is further considered in more detail.

In order to estimate quantitatively the analogies between the directions of the magnetic field and of the elements of fine structure, we plotted the frequency distribution by angles between the direction of the lines of force and that of filaments. At the same time, if the angle between the filament and the line of force remained constant along the total length of the former, this was considered as a single case. When the angle varied along the filament's length, it was measured at two spots and both cases were plotted in the graph. The results thus obtained are shown in Fig. 9 next page. The angles between the directions of the lines of force and filaments are plotted in abscissa and the number of cases is in ordinates. It may be seen from that figure, that $\sim$70 % of the total number of filaments run along the lines of force of the magnetic field with a precision to 5°, and only $\sim$30 % are directed at greater angles to the field. The number of filaments directed at greater angles to lines of force is insignificant.

As recalled above, spectroheliograms were obtained at certain days at the center as well as at various parts of the line H_α, i.e. at different heights in the chromosphere. In our spectroheliograms one can trace the filament orientation to distances of 0.6 Å from the center of the line H_α. According to [9], the center of the line H_α forms in the chromosphere at the height of 5000 km, while the contour emission,

corresponding to the distance of 0.6 Å from the line's center forms at 3000 km.

Comparison of the orientations of filaments situated at various heights in the chromosphere, was also conducted by way of their drawing by spectrograms obtained in various parts of the line. Such sketches were superimposed by spots and daily parallels. Examples of such sketches are shown in Fig. 10 – 12, where solid lines indicate the filament contours for the center of H_α , and the dashes — in the wing. at the distance $\Delta\lambda$ from the center (in Figs 10 and 11 $\Delta\lambda = 0.45$ and 0.59 Å respectively for the observations of 26 June, and in Fig. 12 $\Delta\lambda = 0.30$ Å for the observations of 13 July).

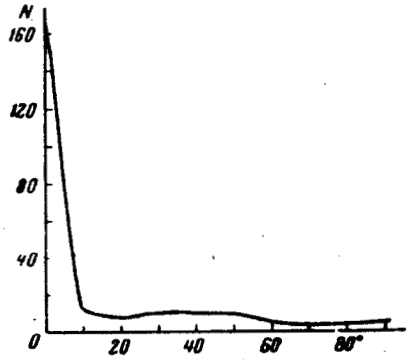

Fig. 9.- Frequency distribution of filaments as a function of angles between the directions of lines of forces and filam.

As a result of such comparison it was found that the orientation of filaments at various heights in the chromosphere (from 3000 to 5000 km) follows in most of the cases the same directions. As was already mentioned above, these directions usually coincide with the direction of the lines of force of the magnetic field at chromosphere level. This is clearly seen in Fig. 8, where a good correspondence exists between the directions of the lines of force and of filaments obtained in the blue wing of the line ($\Delta\lambda = 0.45$ Å).

For 7 September 1962 we were able to investigate not only the orientation of chromosphere's fine structure relative to the magnetic field registered in the photosphere, but also that of granules in the penumbra, situated at about the same level at which the registration of the magnetic field took place.

We have plotted by solid lines on the magnetic field chart of Fig.13 (same part of the chart as in Fig. 6) the contours of the fine structure in spot penumbra. It may seen from that figure that an analogy exists in the orientation of penumbra and magnetic field structure, to which it was pointed also in referenccs [10, 11].

Unfortunately, this case was unique with us, and no final conclusions can be drawn at this time. However, one may remark, that, apparently, the agreement between the direction of the fine structure and of the magnetic field at chromosphere level (Fig. 6) is somewhat better than in the photosphere (Fig.13). This possibly linked with the decreased chromosphere density over the spots [12, 13], which eases the control of matter motion by the magnetic field.

3. - Direct measurements of line splitting in the spectrograms, and the photoelectric registrations made by Severnyy and Bumba [14] have shown that fields of 300 — 500 gauss exist in the chromosphere above the region of sunspots. The registrations of longitudinal fields in the line H_3 CaII also speak of the presence of notable fields in the Sun's chromosphere [15]. That is why the presence of magnetic fields in the chromosphere can hardly induce any doubts. Because of the great conductuvity of the matter in the chromosphere a magnetic field of $\sim$2.3 gauss will orient the motion of filaments, whose mean velocity is $\sim$5 km/s [16]. In other words, one may estimate that the orientation of the fine structure of the chromosphere is determined by the action of forces of the magnetic field. In connection with this it is apparently possible to estimate that the differentiation at some spots of chromosphere's fine structure orientation from the direction of the magnetic field in the photosphere is connected with the difference in the orientation of the fields at these levels. To say, to what extent this discrepancy is real, is impossible on the basis of the material available. The fact of matter is, that according to what was shown by Severnyy [17] and more particularly in the region of large fields, polarization plane rotation takes place. That is why the registrations of the magnetic fields, utilized by us, may differ from the true ones.

Another cause leading to a certain discrepancy in the orientation of the magnetic field and of the fine structure may be the result of the fact, that the registrations were conducted some time after photographing spectroheliograms. A certain variation in the orientation of the magnetic field in time is thus possible [17] Additional research is necessary.

Fig. 10.- Drawing of the fine structure of the chromosphere in the active region for 26 June 1962

Solid lines — center of H_α ; dashes — $\Delta\lambda = 0.45$ Å
Δt: Interval between spectroheliograms = 21 m.

Fig. 11.- Same as for Fig. 10.

Solid lines — center of H_α ; dashes — $\Delta\lambda = 0.59$ Å;
$\Delta t = 28$ m.

Fig. 12. - Drawing the fine structure of the active region for 13 July 1962.

solid lines — center of H_α ; dashes — $\Delta\lambda = 0.30$ Å; $\Delta t = 9$ m.

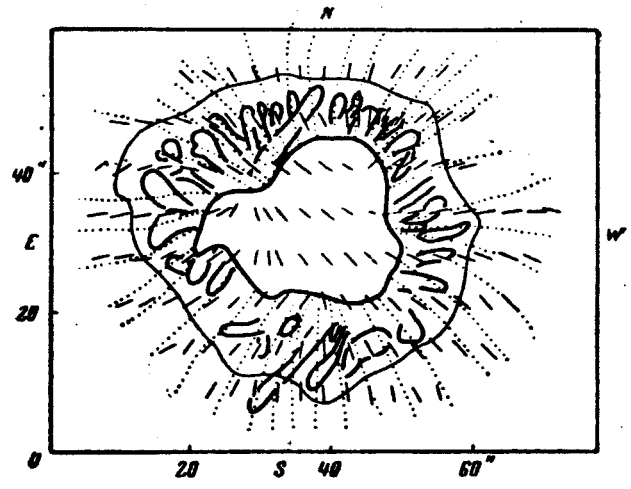

Fig. 13. - Scheme ofAzimuths of the vector of H in the pictorial plane and of the fine structure of the penumbra in integral light for 7 September 1962., $t_1 = 8$h. 51m.

The denotations are the same as in Fig. 2.

In conclusion, the author expresses his deep appreciation to A. B. Severnyy, and S. I. Gopasyuk for the useful discussion of the work.

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